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The Use of Spatial Analysis Techniques in Mapping Potential Natural Hazard Areas: A Case Study of Taiwan.

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Abstract

In 2005, the World Bank issued Natural Disaster Hotspots: A Global Risk Analysis, which indicted that Taiwan, may be the most vulnerable place to natural hazards. This paper aims at landslide points, land use data, socioeconomic indicators integrated with the mapping method to analyze the relation between spatial structural relationships and spatial patterns of disaggregate and aggregate levels in natural hazard areas. First, natural hazard locations are derived from geospatial data and coded into a GIS system. Second, the spatial analysis techniques includes different geospatial scale is derived from spatial autocorrelation analysis (SAA), space syntax. On the other hand, spatial analysis data such as digital terrain model (DTM) combination based on land use type relative significance to the process of landslide occurrence. Finally, this paper organizes a framework integrated with the land use plan and spatial analysis techniques (FILS). Results from 2006 showed that the natural hazard area hot spots include Taipei, Taichung, and Kaohsiung.

Keywords: Spatial autocorrelation analysis; Digital terrain model (DTM); Space syntax

1. Introduction

Natural hazard areas are among the most severe risks to human lives and properties, and have become more frequent and severe along with local economical development. In 2005, the World Bank issued Natural Disaster Hotspots – A Global Risk Analysis, which indicted that Taiwan may be the place on Earth most vulnerable to natural hazards, with 73 percent of its land and population exposed to three or more hazards. In addition, More than 90 percent of the population lives in areas at high relative risk of death from two or more hazards. Typically, natural hazard spatial patterns are loosely defined on the basis of a simple count of natural hazards by some geographical unit, without regard to integrated factors, such as spatial scale, nature surface, land use structure, socioeconomic indicators, the transportation network and compound issues related to the geographical scale of analysis. This paper proposes integrated natural hazards, based on a spatial analytical perspective, such as land cover change theories (Naef et al. 2002;

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Hunducha and Ba´rdossy 2004; Brath et al. 2006), landscape theories (Forman, 1995; Singh, 2007; Steinitz, 2008), GIS, and spatial analysis models (Hong, 2007), then indicating briefly how these could be operational, to examine the risk distribution of natural hazard areas. Specifically, this paper focuses on natural hazard area mapping. First, natural hazard locations are derived from geospatial data and coded into the GIS system. Second, in addition to typical natural hazard area mapping, we also use different geospatial scale mapping potential natural hazard area and mapping socioeconomic indicators. We are particularly interested in the similarities and differences between the spatial patterns in these measures determined from (1) spatial analysis models and spatial autocorrelation theory, (2) other spatial techniques, like the digital terrain model (DTM) and (3) Space Syntax. Finally, this paper organizes a framework integrated with the land use plan and spatial analysis techniques (FILS). Consequently, the reasonable adjustment, planning, and construction of land planning favourably accorded with the functions of a natural, economic and social compound system, and promoted sustainable utilization of land resources and social and economic sustainable development.

2. Architecture of the FILS for landslide

The architecture of the FILS system is presented in Fig. 1. The key aim of this paper is to build a comprehensive plan framework to present the mapping of potential natural hazard areas based on the natural hazard, natural environment and social development for land use planning in Taiwan.

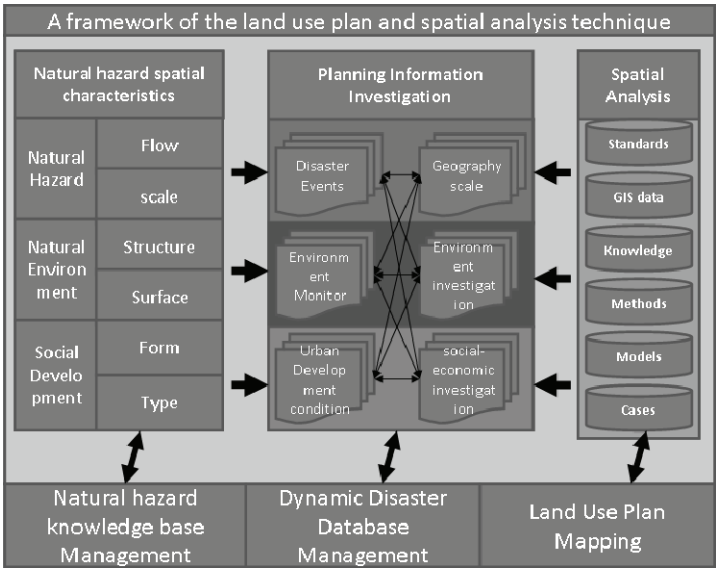

Fig.1. A framework integrated with the land use plan and spatial analysis techniques.

A spatial analysis technique was used to analyze several factors, including flow, scale, terrain, population, urban form and land use that play a dominant role in potential natural hazard occurrences. The overlay operation in GIS is mostly used in this research for potential natural hazards area maps. Planning measures at regional, neighbourhood and station levels are the one of the political and geographic ways to reduce modifiable areal unit problem (MAUP) issues. As a result, a government of work has begun to identify the prevention countermeasures conflict between the local scale and the broader geographic scale, the level at which the discourse of land use planning can be politically addressed. Planning measures of terrain, runoff and soil are one of the landscape and geographic ways to

monitor natural environment change issues. Natural landscape monitoring can provide effective management to integrate pattern and process. The highly complex and dynamic of potential natural hazard areas is particularly amenable to monitoring terrain, runoff and soil conditions. Planning measures for population, industry and urban form are one of the social and geographic ways to control urban development issues. The urban and natural interaction development has begun to identify kinds of the adaptive processes, such as common property, ecological economics or adaptive management, to conceptualize social-ecological linkages in different ways. In addition, the urban development application spatial techniques explore the potential natural hazard areas to control the urban development strategy.

3. Flow process and complicated scale system

The goal of landslides explore discovery is to find out hidden information from a mass of problems to help urban planning in Taipei. This paper through FILS in where landslides areas and the analysis used the data from Taipei in 2004.

3.1. Regional scale

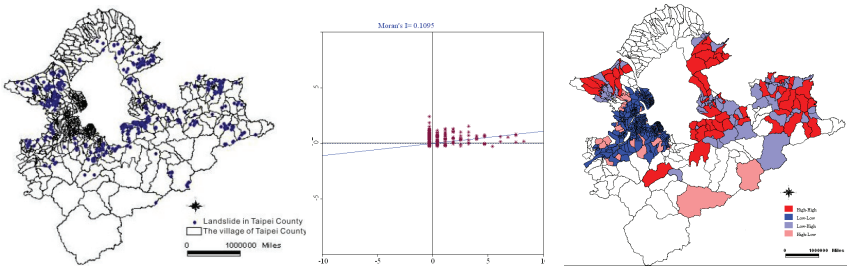

Fig.2. (a) The Landslide map on regional scale; (b) The Moran's Index analysis; (c) The LISA analysis

The value of Moran's Index is positive 0.109, and refers to the random and independent distribution in the region. LISA provides an alternative perspective by focusing on patterns surrounding individual observations and some outliers. Most of the potential natural hazard areas are located in the east and west areas. In the future, land use planning suggests strengthening prevention in such places as Gongliao, Jinshan and Linkou Township in Taipei, as shown in Fig.2.

3.2. Neighborhoods scale

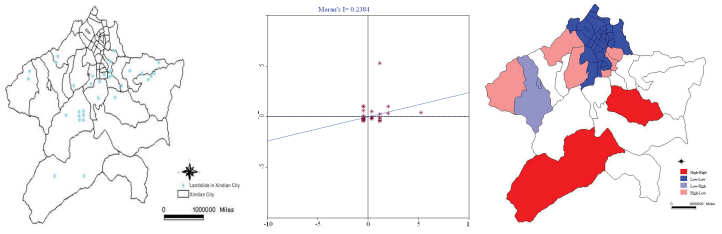

Fig. 3. (a) The Landslide map on neighborhoods scale; (b) The Moran's Index analysis; (c) The LISA analysis

The value of Moran's Index is positive 0.238, and refers to the random and independent distribution in the neighborhood. The use of aggregate data for the evaluation of hazard distribution also entails

methodological problems—the main one being the ecological fallacy or the ecological inference problem. This problem is strongly related to the modifiable areal unit problem (MAUP), which stems from using aggregate data sets at different scales or with different geographical partitions. Geographic scale helps urban planners to explore strong probability of fatalities and assemble damage spatial phenomenon as nature hazards are spreadable. In the future, land use planning suggests strengthening prevention in such places as the Kwong Hing neighborhood, Cukeng neighborhood in Sin Dian area, as shown in Fig.3.

3.3. Station scale

Fig.4. (a) Wusung River profile; (b) The Landslide map and land use map o the station

The Wusung River case is among the most severe risks to residential zones and properties, and has become more frequent and severe along with local economical development. As shown in Fig. 4. Therefore, floods that once occurred infrequently during re-development periods have now become more frequent and more severe due to the transformation of the watershed from rural to urban land uses. Finally, the program could compare target problems with those found cases in characters and then provide solutions for urban planner decision. If the answers are helpful, this case would be added into the case base for FILS. .It is of interest to know, at least statistically, where in Taipei what kind of facilities is at a higher risk. The conservation zone in Taipei is at the highest risk, following by Scenic Zone, Residential zone, Industrial zone, and National Park.

4. Landscape structure and surface system

Recently, many environment models using information on topography available from DTA have been developed, whereas models like SHE and TOPMODEL were adapted to a new type of data which can benefit from the GIS techniques. Three digital base maps are prerequisite in the model to define the watershed drainage work and derive spatial model parameters, i.e. DTA, soil type and land use. This paper uses digital terrain analysis to construct the geometry of Taichung areas in 3 dimensional spaces and to create a continuous rendered mesh of polygons where natural hazard areas occur. The widespread availability of digital geographic data and GIS techniques opens new opportunities for using distributed models in assessing land use impacts on natural hazard areas, as shown in Fig. 5.

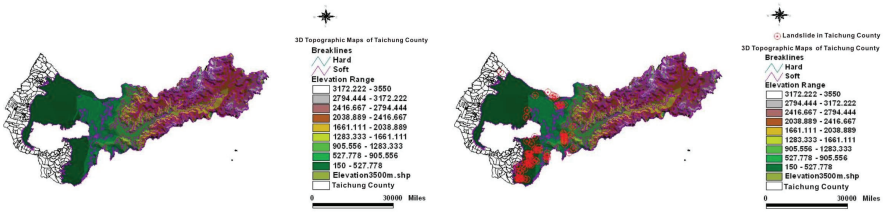

Fig.5. (a) 3D digital terrain analysis; (b) Landslide mapping digital terrain on Taichung.

Due to the intuitive result, large-scale 3D environmental modelling is becoming more and more popular. The digital terrain model is constructed using real world measurement landscape structure and surface system data of GIS, in terms of digital elevation data and satellite image data. A pyramidal data arrangement structure is used for dealing with the requirements of terrain details with different resolutions. The result show the 3 dimensional digital terrain model mapping nature hazard points to find potential natural hazard areas in Taichung. Most of the potential natural hazard areas are located at 517.3 m.

5. Urban form and social type system

This paper uses cases studies of natural hazard areas in Kaohsiung areas in 2006 for analysis. This paper was developed by urban development condition and social-economic investigation of social-economic database of Technology to help urban planners in Taiwan for their decision-making process.

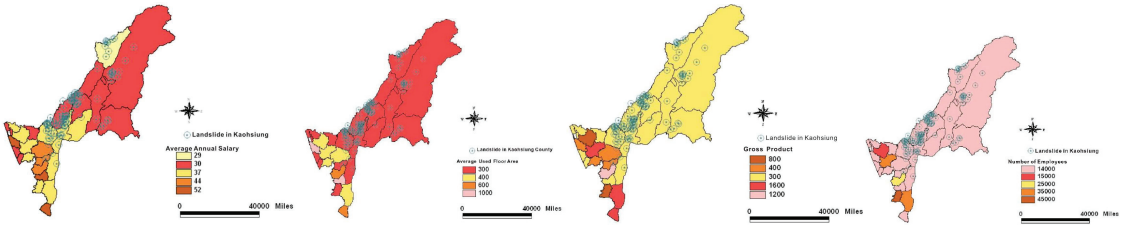

Fig. 7 (a) Landslide mapping average annual salary; (b) Landslide mapping average used floor area; (c) Landslide mapping gross product; (d) Landslide mapping number of employees

The results show that high potential landslide area is mostly in the mountains, in Kaohsiung. Economic indicators include average used floor area, gross product, number of employees and average annual salary reflecting the natural environment and higher levels of disaster impacts, as shown in Fig 7. The large Industry databases and GIS provide enormous amounts of data that can be applied as needed to potential landslide area. If the answers are helpful, this case would be added into the case base for FILS.

6. Conclusion

Natural hazards in land use planning have become a critical issue in many countries. However, because of a lack in sufficient natural hazard related information, planners usually cannot do well in their work. A framework integrated with the land use plan and spatial analysis techniques provides a possible way for knowledge acquisition from GIS database to support urban planners in decision-making process. In fact, natural hazards are a multidimensional issue. Most of the studies have targeted a single spatial analysis technique in natural hazard areas. This FILS was designed as a concept with natural hazard knowledge base management system, dynamic disaster database management, and land use plan mapping technology

to help urban planners in their work. In the two cases, it is illustrated that with the "foresee "ability, This FILS can be further enhanced with the incorporation of GIS for the monitoring of spatial distribution of landslide, and identifying the areas prone to triggering landslide hazards in zones that experience torrential rainfall, and in combination with the QPESUMS and CPAMI for help experts judging the location of the potential landslide hazards.

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